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APPLICATION FOR UNITED STATES LETTERS PATENT

Title:

LOW POLARITY DIMERATE AND TRIMERATE ESTERS AS PLASTICIZERS FOR
ELASTOMERS

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LOW POLARITY DIMERATE AND TRIMERATE ESTERS AS PLASTICIZERS FOR ELASTOMERS

CROSS REFERENCE TO RELATED APPLICATION

This claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional
5 Patent Application Serial No. 60/396,453, filed July 17, 2002, the entire disclosure of
which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention is directed to low polarity dimerate and/or
trimerate esters for plasticizing elastomers, including natural and/or synthetic rubbers.

10

BACKGROUND

A number of elastomers are very difficult to plasticize. For example,
elastomers, such as EPDM, are difficult to plasticize since it is difficult to find
plasticizers that are sufficiently compatible to avoid the plasticizer exuding (bleeding)
to the surface of the elastomer upon cooling and solidification of the elastomer.
15 Usually, hydrocarbon oils such as naphthenic oils or paraffinic oils are used to
plasticize elastomers such as EPDM. While hydrocarbon-based processing oils can
be used with partial success, the resulting plasticized compositions lack advantageous
low temperature properties and the processing oils have a tendency to exude (bleed)
to the surface of the elastomeric article. Attempts to use conventional linear dibasic
20 acid esters, such as dioctyl adipate, dioctyl sebacate, and di-2-ethylhexyl sebacate, or
phthalate esters, such as di-2-ethylhexyl phthalate, have also been unsuccessful since
such conventional ester plasticizers are either incompatible with the elastomer,
resulting in exudation of the plasticizer, or are too volatile for many elastomer uses.

U.S. Patent No. 5,290,886 teaches using organic ester plasticizers to
25 plasticize thermoplastic elastomers comprising a blend of a thermoplastic polyolefin
and an elastomer to lower the glass transition temperature (T_g) of both the elastomer
and the polyolefin phases and to improve impact strength at low temperatures. The
'886 patent neither discloses nor suggests using the cyclic dimerate and/or cyclic

trimerate esters disclosed herein, and found that "polymeric dibasic esters and aromatic esters were found to be significantly less effective" (column 3, lines 62-64).

Dimer acid esters have been proposed as plasticizers for high temperature resistant fluorocarbon polymers (see U.S. Patent No. 4,078,114) and for plasticizing anhydride-functionalized polymers (see U.S. Patent No. 5,169,716) but have not been suggested for plasticizing non-fluorocarbon polymers, non-anhydride-functionalized polymers, or elastomers. It is preferred that the elastomers plasticized with the dimerate and/or trimerate esters disclosed herein are not fluorocarbon polymers, fluorocarbon elastomers, anhydride-functionalized polymers, or anhydride-functionalized elastomers.

Surprisingly and unexpectedly, dimerate and/or trimerate esters designed to have very low polarity act as efficient plasticizers for elastomers. The resulting plasticized compositions have excellent low temperature properties and exhibit little or no tendency of the plasticizer to exude or bleed to the surface of the elastomer composition. Use of the dimerate and/or trimerate esters as disclosed herein provides an advantageous balance of flexibility, impact resistance, and strength to the plasticized elastomers.

SUMMARY OF THE INVENTION

In brief, it has been found that the use of cyclic dimerate and/or trimerate esters, formed from mono-, di-, and/or tri-carboxylic acids containing one, two, or three C₃-C₂₄ radicals or fatty acid residues and C₃-C₂₄ alkyl alcohols, in a natural or synthetic vulcanizable rubber, unexpectedly increases the low temperature properties of the rubber for uses such as, hoses, belts, conveyor belts, motor mounts, gaskets, automotive drive train belts, including transmission belts, roofing compounds, and the like. By adding one or more cyclic dimerate and/or trimerate esters (di- and/or tri-esters), particularly dimerate esters derived from C₁₈ fatty acids and C₃-C₂₄ alcohols, preferably, C₃-C₁₈ alcohols, more preferably, C₆-C₁₈ alcohols, the low temperature properties of the elastomer are surprisingly improved. Preferably, the esters are formed by reacting a C₃-C₁₈ alcohol with a mixture of mono-

, di-, and tri-fatty acids, *e.g.*, primarily C₁₈ carboxylic acids, and their dimers and trimers.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

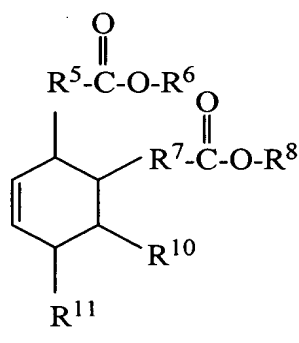
5 The cyclic dimerate and/or trimerate ester plasticizers described herein are added to one or more natural or synthetic rubbers, preferably together with a vulcanizing agent. Surprisingly, the cyclic ester plasticizers disclosed herein significantly increase the low temperature properties of the rubber composition and provide an excellent and unexpected balance of flexibility, impact resistance, and strength to the elastomer composition.

10 The cyclic esters may be diesters, triesters, or mixtures thereof, including saturated or unsaturated hydrocarbon chains, straight chain or branched, having zero to six double bonds in the hydrocarbon chains. While cyclic monoesters are less preferred, they also may successfully be used in accordance with the present disclosure.

15 Many of the cyclic diester and/or cyclic triester materials are formed from self reaction of naturally derived fatty acid mixtures containing oleic, linoleic, and linolenic acids, and consequently are blends of mono-, di-, and tri-carboxylic acid esters. The blends may further include other compounds that do not adversely affect the advantages imparted to elastomers by the subject cyclic dimerate and/or trimerate
20 esters described herein.

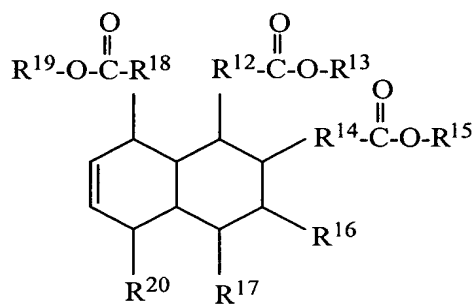
 Ranges may be expressed herein as from “about” or “approximately” one particular value and/or to “about” or “approximately” another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as
25 approximations, by use of the antecedent “about,” it will be understood that the particular value forms another embodiment.

The cyclic diesters, referred to herein as dimerates, have a formula I, as follows:



- wherein R^5 and R^7 , same or different, are C_3 - C_{24} , preferably C_6 - C_{24} , more preferably C_8 - C_{18} hydrocarbon chains, straight chain or branched, either saturated or containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds;
- R^6 and R^8 , same or different, are C_3 - C_{24} , preferably C_3 - C_{18} , more preferably C_6 - C_{18} alkyl, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds; and
- R^{10} and R^{11} , same or different, are C_3 - C_{24} , preferably C_3 - C_{18} , more preferably C_6 - C_{18} saturated hydrocarbon chain, straight chain or branched; or an unsaturated C_3 - C_{24} , preferably C_3 - C_{18} , more preferably C_6 - C_{18} hydrocarbon chain, straight chain or branched, containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds.

The cyclic triesters, referred to herein as trimerates, have a formula II, as follows:



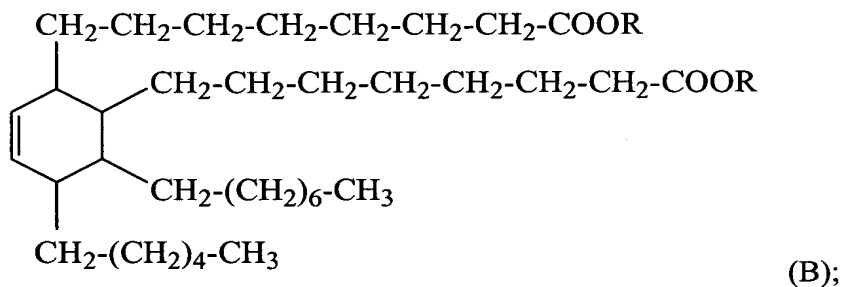
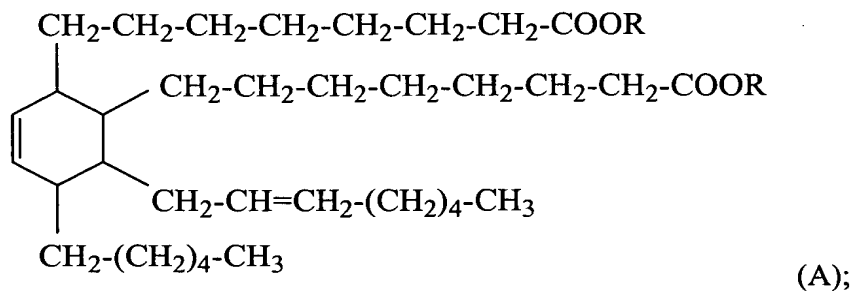
wherein R¹², R¹⁴ and R¹⁸, same or different, are C₃-C₂₄, preferably C₆-C₂₄, more preferably C₈-C₁₈ hydrocarbon chain, straight chain or branched, either saturated or containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds;

5 R¹³, R¹⁵ and R¹⁹, same or different, are C₃-C₂₄ alkyl, preferably C₃-C₁₈ chains, more preferably C₆-C₁₈ alkyl, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds; and

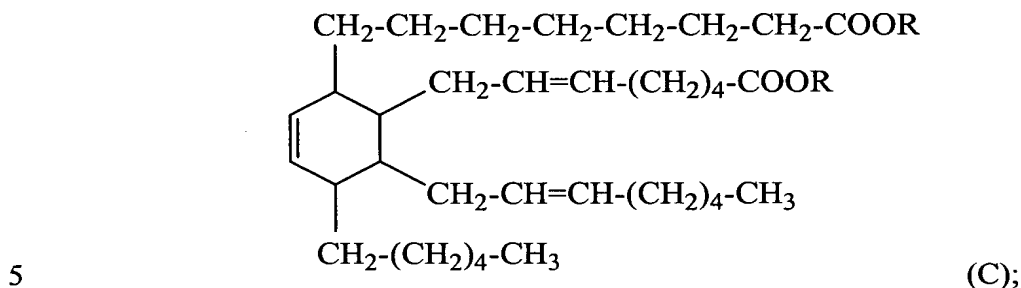
10 R¹⁶, R¹⁷ and R²⁰, same or different, are C₃-C₂₄, preferably C₃-C₁₈, more preferably C₆-C₁₈ saturated hydrocarbon chains, straight chain or branched; or unsaturated C₃-C₂₄, preferably C₃-C₁₈, more preferably C₆-C₁₈ hydrocarbon chains, straight chain or branched, containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds.

The low polarity of the cyclic ester compounds disclosed herein is important for successfully plasticizing elastomeric compositions. Low polarity cyclic ester compounds, *e.g.*, ester compounds formed from dimer acids and alcohols having a single hydroxyl group are preferred. Similarly, it is preferred that R⁶, R⁸, R¹³, R¹⁵,
15 and R¹⁹ of formulas I and II do not contain hydroxyl substituents. Dimerate esters formed from dimer acids and glycol type alcohols, for example, glycol alcohols such as ethylene glycol, diethylene glycol, triethylene glycol, and other polyethylene glycols, would be too polar to plasticize elastomeric compositions while simultaneously providing superior low temperature properties. Additionally, esters
20 prepared by reacting dimer acids with the glycol functionalized monomers and oligomers set forth in U.S. Patent No. 4,054,561 would also be too polar for use as plasticizers.

Useful cyclic diesters falling within formula I include dimerate ester structures formed by the reaction of C₃₆ dimer acid derived from tall oil fatty acids
25 and C₃-C₂₄, preferably C₃-C₁₈, more preferably C₆-C₁₈ alcohols, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds. Examples of such cyclic esters include the following structures, wherein the dimer acid corresponding to structure A is formed by self reaction of linoleic acid, the dimer acid corresponding to structure B is formed by reacting linoleic acid with oleic acid,
30 and the dimer acid corresponding to structure C is formed by reacting linoleic acid with linolenic acid:



and

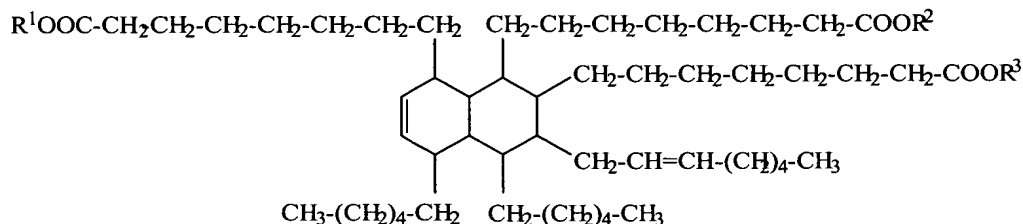


wherein each R, same or different, in formulas (A), (B), and (C) is a C₃-C₂₄ preferably C₃-C₁₈ hydrocarbon chain, more preferably C₆-C₁₈, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds.

10 RX-13804 and RX-13824 are the subject plasticizers of several of the exemplified compositions reported in the Examples, and are additional examples of dimerate esters in accordance with formula I. RX-13804 is formed by the reaction of a predominantly C₃₆ dimer acid with 2-ethylhexyl alcohol. RX-13824 is formed by the reaction of a predominantly C₃₆ dimer acid with tridecyl alcohol. An additional

example of a plasticizer in accordance with formula I is formed by the reaction of a predominantly C₃₆ dimer acid with oleyl alcohol.

A representative example of the triester (trimerate ester) of formula II is the following structure (D):



5

(D);

wherein each R¹, R², and R³, same or different, is a C₃-C₂₄, preferably C₃-C₁₈, more preferably C₆-C₁₈ hydrocarbon chain, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds.

10

In the present description, the term dimerate is sometimes used by itself when referring to a blend including structures of formulas I and II (*i.e.*, blend including dimerates and trimerates).

15

The cyclic ester plasticizers of formula I, II, or mixtures thereof are typically added to an elastomer composition comprising natural and/or synthetic rubber in an amount of about 0.1 parts to about 50 parts by weight, preferably from ranges about 2 parts to about 40 parts, more preferably from about 10 parts to about 35 parts per 100 parts by weight of rubber.

20

A particularly useful blend of carboxylic acids for forming cyclic esters in accordance with the disclosure is a blend of carboxylic acids having CAS#: 61788-89-4, and known as dimer acid. Dimer acid is a blend including primarily C₃₆ and C₅₄ dimer and trimer acids, and predominantly (more than 50% by weight) C₃₆ dimer acid.

25

The fatty acid residues or hydrocarbon chains R⁵, R⁷, R¹², R¹⁴ and R¹⁸ of the esters of formulas I and II can be any C₃-C₂₄, preferably C₆-C₂₄, more preferably C₈-C₁₈ hydrocarbon chain, either saturated or containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds, and may be derived from animal or vegetable

fatty acids such as butter; lard; tallow; grease; herring; menhaden; pilchard; sardine; babassu; castor; coconut; corn; cottonseed; jojoba; linseed; oiticica; olive; palm; palm kernel; peanut; rapeseed; safflower; soya; sunflower; tall; and/or tung. Examples are the hydrocarbon chain residues from the following fatty acids, where the number in
5 parentheses indicates the number of carbon atoms, and the number of double bonds, *e.g.*, (C₂₄₋₆) indicates a hydrocarbon chain having 24 carbon atoms and 6 double bonds: hexanoic (C₆₋₀); octanoic (C₈₋₀); decanoic (C₁₀₋₀); dodecanoic (C₁₂₋₀); 9-dodecenoic (CIS) (C₁₂₋₁); tetradecanoic (C₁₄₋₀); 9-tetradecenoic (CIS) (C₁₄₋₁); hexadecanoic (CIS) (C₁₆₋₀); 9-hexadecenoic (CIS) (C₁₆₋₁); octadecanoic (C₁₈₋₀); 9-
10 octadecenoic (CIS) (C₁₈₋₁); 9,12-octadecadienoic (CIS, CIS) (C₁₈₋₂); 9, 12, 15-octadecatrienoic (CIS, CIS, CIS) (C₁₈₋₃); 9, 11, 13-octadecatrienoic (CIS, TRANS, TRANS) (C₁₈₋₃); octadecatetraenoic (C₁₈₋₄); eicosanoic (C₂₀); 11-eicosenoic (CIS) (C₂₀₋₁); eicosadienoic (C₂₀₋₂); eicosatrienoic (C₂₀₋₃); 5, 8, 11, 14-eicosatetraenoic (C₂₀₋₄); eicosapentaenoic (C₂₀₋₅); docosanoic (C₂₂); 13-docosenoic (CIS) (C₂₂₋₁);
15 docosatetraenoic (C₂₂₋₄); 4, 8, 12, 15, 19-docosapentaenoic (C₂₂₋₅); docosaheptaenoic (C₂₂₋₆); tetracosenoic (C₂₄₋₁); and 4, 8, 12, 15, 18, 21-tetracosahexaenoic (C₂₄₋₆).

Commercially available blends of useful polybasic acids that can be reacted with C₃-C₂₄, preferably C₃-C₁₈, more preferably C₆-C₁₈ alcohols, straight chain or branched, saturated, or unsaturated containing 1 to 3 carbon-to-carbon double
20 bonds to produce the dimerate and trimerate esters, as blends, include the following: EMPOL® 1010 Dimer Acid; EMPOL® 1014 Dimer Acid; EMPOL® 1016 Dimer Acid; EMPOL® 1018 Dimer Acid; EMPOL® 1022 Dimer Acid; EMPOL® 1024 Dimer Acid; EMPOL® 1040 Trimer Acid; EMPOL® 1041 Trimer Acid; EMPOL® 1052 Polybasic Acid; and similar PRIPOL™ products from Uniqema as well as
25 UNIDYME® products from Arizona Chemical.

Particularly useful ester additives are made by reacting any of the long chain mono, dimer and/or trimer acids with one or more straight chain or branched C₃-C₂₄, preferably C₃-C₁₈, more preferably C₆-C₁₈ alcohols to produce esters in
30 accordance with formulas I and II. The above dimer, trimer, and polybasic acids are produced by dimerizing, trimerizing, and polymerizing (oligomerizing) carboxylic acids, typically C₁₈ fatty acids. The fatty acids are typically mixtures. For example,

the dimer acid produced from a C₁₈ carboxylic acids (*e.g.*, a mixture of stearic, oleic, linoleic, and linolenic) will result in a blend of numerous cyclic dimerate and trimerate esters, as in formulas I and II, some saturated and some containing hydrocarbon chains having 1 to 6, generally 1 to 3 carbon-to-carbon double bonds.

- 5 Any one or any blend of the esters that include the cyclic dimerate and/or cyclic trimerate esters in accordance with formulas I or II will function to plasticize elastomers, and provide a balance of flexibility, strength, and low temperature properties, with essentially no bleeding of the plasticizer to the surface of an elastomeric article. Particularly, the plasticized elastomeric compositions described
- 10 herein are characterized in that the low temperature properties are improved to provide a balance of good flexibility and strength at low temperatures.

Rubbers useful in the compositions described herein can be natural rubbers (NR) and/or synthetic rubbers.

- Synthetic rubbers include homopolymers of conjugated diene
- 15 compounds such as isoprene, butadiene, chloroprene, and the like, for example, polyisoprene rubber (IR), polybutadiene rubber (BR), polychloroprene rubber, and the like; copolymers of the above described conjugated diene compounds with vinyl compounds such as styrene, acrylonitrile, vinyl pyridine, acrylic acid, methacrylic acid, alkyl acrylates, alkyl methacrylates, and the like, for example, styrene-butadiene
- 20 copolymeric rubber (SBR), vinylpyridine-butadiene-styrene copolymeric rubber, acrylonitrile-butadiene copolymeric rubber, acrylic acid-butadiene copolymeric rubber, methacrylic acid-butadiene copolymeric rubber, methyl acrylate-butadiene copolymeric rubber, methyl methacrylate-butadiene copolymeric rubber, acrylonitrile-butadiene-styrene terpolymer, and the like; copolymers of olefins, such as ethylene,
- 25 propylene, isobutylene, and the like with dienes, for example, isobutylene-isoprene copolymeric rubber (IIR); copolymers of olefins with non-conjugated dienes such as ethylene propylene diene monomer (EPDM), for example, ethylene-propylene-cyclopentadiene terpolymer, ethylene-propylene-5-ethylidene-2-norbornene terpolymer and ethylene-propylene-1,4-hexadiene terpolymer; polyalkenamer
- 30 obtained by ring opening polymerization of cycloolefins, for example, polypentenamer; rubbers obtained by ring opening polymerization of oxirane ring, for

example, polyepichlorohydrin rubber and polypropylene oxide rubber which can be vulcanized with sulfur, and the like. Furthermore, halides of the above-described various rubbers, for example, chlorinated isobutylene-isoprene copolymeric rubber (Cl-IIR), brominated isobutylene-isoprene copolymeric rubber (Br-IIR), fluorinated
5 polyethylene, and the like are similarly included.

Particularly, the compositions described herein are characterized in that low temperature properties of natural rubber (NR), and synthetic rubbers, e.g. styrene-butadiene copolymeric rubber (SBR), polybutadiene rubber (BR), polyisoprene rubber (IR), isobutylene-isoprene, copolymeric rubber, halides of these
10 rubbers (Cl-IIR, Br-IIR) and copolymers of olefins with non-conjugated dienes are improved to provide the rubbers with a balance of good flexibility and strength at low temperatures. Of course, the present invention can be applied to other rubbers. All these rubbers may be kneaded with compounding agents conventionally used for compounding with rubber, for example, fillers, such as carbon black, silica, calcium
15 carbonate, lignin and the like, softening agents, such as mineral oils, vegetable oils, prior to vulcanization and then vulcanized.

In order to cure a rubber composition a vulcanizing agent such as a sulfur or peroxide vulcanizing agent is dispersed throughout the composition. The amount of vulcanizing agent, *e.g.*, sulfur, in the composition is typically from about 2
20 to about 8 parts, for example from about 3 to about 6, by weight per 100 parts by weight of natural and/or synthetic rubber, but lesser or larger amounts, for example, from about 1 to 7 or 8 parts may be employed on the same basis. A preferred range is from about 2.5 to about 6 parts per 100 parts by weight of rubber. Representative examples of sulfur vulcanizing agents include elemental sulfur (S_8), amine disulfides,
25 polymeric polysulfides, and sulfur olefin adducts. Preferably, the sulfur vulcanizing agent is elemental sulfur.

The term "vulcanization" used herein means the introduction of three dimensional cross-linked structures between rubber molecules. Thus, thiuram vulcanization, peroxide vulcanization, quinoid vulcanization, resin vulcanization,
30 metal salt vulcanization, metal oxide vulcanization, polyamine vulcanization, radiation vulcanization, hexamethylenetetramine vulcanization, urethane cross-linker

vulcanization and the like are included in addition to sulfur vulcanization, which is usual and most important.

Accelerators may be used to control the time and/or temperature required for vulcanization and to improve the properties of the vulcanizate. The accelerator(s) may be used in total amounts ranging from about 0.3 parts to about 4 parts, for example about 0.3 parts to about 1.5 parts, preferably from about 0.4 parts to about 1.0 parts, and more preferably from about 0.5 parts to about 0.8 parts by weight per 100 parts by weight of natural and/or synthetic rubbers. Suitable types of accelerators that may be used are amines, disulfides, guanidines, thioureas, thiazoles, thiurams, sulfenamides, dithiocarbamates, and xanthates. If included in the rubber composition, the primary accelerator preferably is typically a sulfenamide. If a second accelerator is used, the secondary accelerator is preferably a guanidine, dithiocarbamate, or thiuram compound. Specific examples of vulcanization accelerators which can be used in the rubber compositions described herein are thiazole-based accelerators, for example 2-mercaptobenzothiazole, bis(2-benzothiazolyl)disulphide, 2(2',4'-dinitro-phenylthio)benzothiazole, benzothiazole-2-sulphenamides, for instance N-isopropyl-benzothiazole-2-sulphenamide, N-tert-butyl-benzothiazole-2-sulphenamide, N-cyclo-hexylbenzo-thiazole-2-sulphen-amide, and 2(morpholiniothio)benzothiazole, and thiocarbamylsulphenamides, for example N,N-dimethyl-N',N'-dicyclohexylthiocarbamoylsulphenamide, and N(morpholiniothiocarbonylthio)morpholine.

The commonly employed carbon blacks used in conventional rubber compounding applications can be used as the carbon black in this invention. Representative examples of such carbon blacks include N110, N121, N220, N231, N234, N242, N293, N299, S315, N326, N330, M332, N339, N343, N347, N351, N358, and N375.

The rubber compositions described herein are compounded by methods generally known in the rubber compounding art, such as mixing the various sulfur-vulcanizable or peroxide-vulcanizable constituent rubbers with various commonly used additive materials such as, for example, sulfur donors, curing aids, such as activators and retarders, and processing additives, such as oils, resins including

tackifying resins and other conventional plasticizers, fillers, pigments, fatty acid, zinc oxide, waxes, antioxidants and antiozonants, retarders, and peptizing agents. As known to those skilled in the art, the additives mentioned above are selected and commonly used in conventional amounts for tire tread applications. A typical amount
5 of adhesive resins is about 0.2 parts to about 10 parts per 100 parts by weight of the natural and/or synthetic rubbers, usually about 1 part to about 5 parts.

Typical amounts of zinc oxide comprise about 2 parts to about 5 parts per 100 parts by weight of natural and/or synthetic rubbers. Typical amounts of waxes comprise about 1 part to about 5 parts per 100 parts by weight of natural and/or
10 synthetic rubbers. Often microcrystalline waxes are used. Typical amounts of retarders range from about 0.05 parts to about 2 parts per 100 parts by weight of natural and/or synthetic rubbers. Typical amounts of peptizers comprise about 0.1 parts to about 1 part per 100 parts by weight of natural and/or synthetic rubbers. Typical peptizers may be, for example, pentachlorothiophenol and
15 dibenzamidodiphenyl disulfide. All additive percentages and amounts are based on the weight of natural and/or synthetic rubbers.

Vulcanization of the rubber composition described herein is generally carried out at conventional temperatures ranging from about 100°C to about 200°C. Preferably, the vulcanization is conducted at temperatures ranging from about 110°C
20 to about 180°C. Any of the usual vulcanization processes may be used such as heating in a press or mold, heating with superheated steam or hot air, or in a salt bath.

Upon vulcanization of the rubber composition at a temperature ranging from about 100°C to about 200°C, the rubber composition can be used for various purposes. For example, the vulcanized rubber composition may be in the form of a
25 tire, belt, hose, motor mounts, gaskets and air springs. In the case of a tire, it can be used for various tire components. Such tires can be built, shaped, molded, and cured by various methods which are known and will be readily apparent to those having skill in such art. When the rubber composition is used in a tire, its use may be in a wire coat, bead coat, tread, apex, sidewall, and combination thereof. As can be
30 appreciated, the tire may be a passenger tire, aircraft tire, truck tire, and the like.

Preferably, the tire is a passenger tire. The tire may also be a radial or bias, with a radial tire being preferred.

The invention may be better understood by reference to the following examples in which parts and percentages are by weight unless otherwise indicated.

5 In the following examples, cyclic dimerate esters were applied to EPDM (Royalene 501 and Royalene 502), natural rubber, and neoprene. Previous work determined that conventional organic esters were either incompatible or too volatile for many elastomer applications.

10 The following Tables I-VI include original physical properties, processing and curing properties, compatibility, low temperature, and heat aging data for elastomeric compositions which have been plasticized with representative dimerate ester compositions or previously known plasticizers. The dimerate esters were evaluated at 30 parts per hundred parts by weight of natural and/or synthetic rubbers (phr) and compared to a conventional paraffinic oil at 60 phr (*i.e.*, the
15 conventional rubber plasticizer was added to an elastomer composition at twice the amount of the rubber plasticizers disclosed herein).

Results

Table I illustrates the use of dimerate esters and conventional plasticizers in an EPDM compound. The processing and curing properties show no major differences when compared with paraffinic oils except that since the dimerates are evaluated at lower phr they do produce higher viscosity compounds.

5 Compatibility data (*i.e.*, lack of roll spew) show all dimerate esters evaluated in Table I are compatible with EPDM. The dimerate esters provide higher tensile strength and hardness values than other plasticizers.

Table I shows the low temperature properties for elastomers plasticized with various compounds. The low temperature properties of the compositions plasticized with the dimerate esters are highly significant in comparison to elastomers plasticized with paraffinic oil. Elastomers plasticized with the dimerates possess better lower temperature properties than elastomers plasticized with paraffinic oil, even though the dimerates are at 30 phr and paraffinic oil is at 60 phr. Elastomers

10 plasticized with dimerates exhibit an unexpected combination of high strength and hardness with excellent low temperature properties, and such properties can have importance in applications such as V-belts, radiator hoses, automotive insulation, seals and gaskets.

15

The air oven aging results show that the dimerates are essentially equal to the paraffinic oil in weight loss. The dimerate esters are significantly lower in volatility when compared to the tallate esters, RX-13577 and RX-13782.

20

TABLE I

Example	1	2	3	4	5	6
Royalene 501	100.00					
N-550	60.00					
Kadox 930	5.00					
Stearic Acid	1.00					
RX-13577	30.00	--	--	--	--	--
RX-13782	--	30.00	---	---	---	---
RX-13804	---	---	30.00	---	---	---
RX-13805	---	---	---	30.00	---	---
RX-13806	---	---	---	---	30.00	---
SUNPAR 2280	---	---	---	---	---	60.00
Subtotal	196.00	196.00	196.00	196.00	196.00	226.00
Mill Addition						
Spider Sulfur	0.80					
Premix MBT	0.9375					
Premix TMTD	0.625					
Premix DPTT	0.625					
Premix TDEC	0.625					
Total	199.61	199.61	199.61	199.61	199.61	229.61
Major Variable	RX-13577	RX-13782	RX-13804	RX-13805	RX-13806	SUNPAR 2280
Processing Properties						
Viscosity and Curing Properties						
Mooney Viscosity at 135°C(275°F)						
Minimum Viscosity	22	21.3	25.9	26.4	25.3	13
t ₅ , minutes	7.9	7.8	5.9	5.9	5.9	9
t ₁₀ , minutes	9.3	9.1	7.2	7.2	7.1	10.8
t ₃₅ , minutes	18.3	20.3	9.6	9.9	9.7	14.7
Oscillating Disc Rheometer at 160°(320°F)						
M _L	4.4	4.1	5.1	5.2	5	2.3
M _H	17.9	15.9	28.1	28.7	28.2	17.4
t ₂ , minutes	2.7	2.8	2.3	2.3	2.2	3.3
t' _c (90), minutes	7.3	6.8	5.7	6	5.5	7.8
1.25*t' _c (90), minutes	9.2	8.5	7.1	7.5	6.9	9.8
Cure Rate Index	21.5	25	29.9	27.3	30	22.2
Vulcanizate Properties						
Roll Spew						
Temperature @ -40°C						
24 hours	NONE	NONE	NONE	NONE	NONE	NONE
48 hours	NONE	NONE	NONE	NONE	NONE	NONE
72 hours	NONE	NONE	NONE	NONE	NONE	NONE
96 hours	NONE	NONE	NONE	NONE	NONE	NONE
Temperature @ -3°C						
24 hours	NONE	NONE	NONE	NONE	NONE	NONE
48 hours	NONE	NONE	NONE	NONE	NONE	NONE
72 hours	NONE	NONE	NONE	NONE	NONE	NONE
96 hours	NONE	NONE	NONE	NONE	NONE	NONE
Temperature @ 25°C						
24 hours	NONE	NONE	NONE	NONE	NONE	NONE
48 hours	NONE	NONE	NONE	NONE	NONE	NONE
72 hours	NONE	NONE	NONE	NONE	NONE	NONE
96 hours	NONE	NONE	NONE	NONE	NONE	NONE

Example	1	2	3	4	5	6
<u>Original Physical Properties</u>						
Stress @ 100% Elongation, MPa	0.8	0.7	1.6	1.8	1.6	1.3
, psi	114	101	236	256	234	188
Stress @ 200% Elongation, MPa	1.1	0.9	3.2	3.5	3.2	2.7
Stress @ 300% Elongation, MPa	1.6	1.2	4.8	5.2	4.8	4.2
Tensile Ultimate, MPa	3.0	2.0	14.4	14.8	14.7	12.1
, psi	435	288	2094	2148	2126	1751
Elongation @ Break, %	744	640	734	689	724	669
Hardness Duro A, pts.	51	50	57	58	57	49
Specific Gravity	1.062	1.062	1.067	1.070	1.067	1.038
Compression Set, % 22hrs. @ 100°C	92	92	69	71	75	68
<u>Low Temperature Properties</u>						
<u>Low Temperature Impact - Brittleness</u>						
Brittle Point, as molded, all pass, °C	<-75	<-75	<-75	-71	<-75	-72
After air oven aging, all pass, °C	<-75	-72	<-75	<-75	<-75	<-75
<u>Low Temperature Torsion - Gehman</u>						
As molded, Relative Modulus						
T2, °C	-4	-6	-21	-26	-13	-26
T5, °C	-39	-34	-51	-47	-33	-41
T10, °C	-55	-43	-55	-55	-44	-46
T100, °C	-67	-70	-66	-65	-61	-55
Apparent Modulus of Rigidity	83.3	90.5	128.8	149.8	131.9	95.5
Temperature at 500 psi, °C						
500 psi, °C	-47	-35	-43	-39	-28	-41
5,000 psi, °C	-65	-59	-62	-59	-56	-53
10,000 psi °C	-68	-68	-65	-62	-59	-55
25,000 psi, °C	-72	-75	-68	-75	-75	-60
50,000 psi, °C	-75	<-75	-75	<-75	<-75	-70
<u>Aged Vulcanizate Properties</u>						
<u>Air Oven Aging, 70h @ 150°C</u>						
Stress @ 100% Elongation, MPa	8.4	9.0	5.4	5.7	5.2	3.0
, psi	1216	1307	777	823	749	433
Stress Change, %	970	1199	230	221	219	131
Tensile Ultimate, MPa	10.5	11.6	7.9	9.8	8.9	7.6
, psi	1520	1689	1151	1428	1290	1109
Tensile Change, %	250	486	-45	-34	-39	-37
Elongation @ Break, %	127	131	140	163	160	207
Elongation Change, %	-83	-80	-81	-76	-78	-67
Hardness Duro A, pts.	80	82	75	71	68	57
Hardness Change, pts.	29	32	18	13	11	8
Weight Change, %	-11	-12	-2.4	-2.3	-2.0	-1.5

The next experiments with dimerate esters were in an EPDM having a different ethylene/propylene ratio (Royalene 502). Again, dimerate esters were evaluated at 30 phr and compared to a conventional paraffinic oil at 60 phr.

Results

The processing and curing properties of the EPDM compositions plasticized with dimerates show no major differences when compared with elastomer compositions plasticized with paraffinic oils except that since the dimerates are evaluated at lower phr they do produce higher viscosity compounds. Compatibility data (*i.e.*, lack of roll spew) show all esters evaluated in Table II are compatible with EPDM. The dimerate esters provide higher tensile strength and hardness values than other plasticizers.

Table II shows the low temperature properties for elastomers plasticized with various compounds. The low temperature properties of the compositions plasticized with the dimerate esters are highly significant in comparison to elastomers plasticized with paraffinic oil. Elastomers plasticized with the dimerates possess better lower temperature properties than elastomers plasticized with paraffinic oil, even though the dimerates are at 30 phr and paraffinic oil is at 60 phr. Elastomers plasticized with dimerates exhibit an unexpected combination of high strength and hardness with excellent low temperature properties, and such properties can have importance in applications such as V-belts, radiator hoses, automotive insulation, seals and gaskets.

The air oven aging results show that the dimerates are essentially equal to the paraffinic oil in weight loss, which is a significant improvement over conventional organic ester plasticizers and tallate compounds.

TABLE II

Example	7	8	9	10	11	12
Royalene 502	100.00					
N-550	60.00					
Kadox 930	5.0					
Stearic Acid	1.0					
RX-13577	30.00					
RX-13782	---	30.00	--	--	--	--
RX-13804	---	---	30.00	---	---	---
RX-13805	---	---	---	30.00	---	---
RX-13806	---	---	---	---	30.00	---
SUNPAR 2280	---	---	---	---	---	60.00
Subtotal	196.00	196.00	196.00	196.00	196.00	226.00
Mill Addition						
Spider Sulfur	0.80					
Premix MBT	0.94					
Premix TMTD	0.63					
Premix DPTT	0.63					
Premix TDEC	0.63					
Total	199.61	199.61	199.61	199.61	199.61	229.61
Major Variable	RX-13577	RX-13782	RX-13804	RX-13805	RX-13806	SUNPAR2280
Processing Properties						
Viscosity and Curing Properties						
Mooney Viscosity at 135°C(275°F)						
Minimum Viscosity	41.7	40.1	48.4	49.3	48.6	26
t5, minutes	6.8	6.6	4.7	4.6	4.8	7.3
t10, minutes	7.9	7.5	5.6	5.4	5.7	8.8
t35, minutes	10.6	9.8	7.8	7.4	7.8	11.8
Oscillating Disc Rheometer at 160°C(320°F)						
M _L	9.8	9.4	11.1	10.8	11.1	5.5
M _H	35	33	47.5	42.5	44.7	29.2
T _{S2} , minutes	2.2	2.2	1.8	1.8	1.7	2.5
t'c(90), minutes	6.3	6	5.5	5.8	5.2	7.8
1.25*t'c(90), minutes	7.9	7.5	6.9	7.3	6.5	9.8
Cure Rate Index	24	26.1	27.3	25	28.6	18.8
Vulcanizate Properties						
Roll Spew						
Temperature @ -40°C						
24 hours	NONE	NONE	NONE	NONE	NONE	NONE
48 hours	NONE	NONE	NONE	NONE	NONE	NONE
72 hours	NONE	NONE	NONE	NONE	NONE	NONE
96 hours	NONE	NONE	NONE	NONE	NONE	NONE
Temperature @ -3°C						
24 hours	NONE	NONE	NONE	NONE	NONE	NONE
48 hours	NONE	NONE	NONE	NONE	NONE	NONE
72 hours	NONE	NONE	NONE	NONE	NONE	NONE
96 hours	NONE	NONE	NONE	NONE	NONE	NONE
Temperature @ 25°C						
24 hours	NONE	NONE	NONE	NONE	NONE	NONE
48 hours	NONE	NONE	NONE	NONE	NONE	NONE
72 hours	NONE	NONE	NONE	NONE	NONE	NONE
96 hours	NONE	NONE	NONE	NONE	NONE	NONE

Example	7	8	9	10	11	12
Original Physical Properties						
Stress @ 100% Elongation, MPa	1.0	0.9	2.0	2.0	1.8	1.5
, psi	150	137	290	287	259	215
Stress @ 200% Elongation, MPa	1.6	1.4	4.2	4.2	3.8	3.2
Stress @ 300% Elongation, MPa	2.5	2.1	6.4	6.4	5.8	5
Tensile Ultimate, MPa	11.2	9.0	15.3	15.3	14.7	12.1
, psi	1629	1301	2216	2221	2126	1752
Elongation @ Break, %	1878	1867	580	576	606	573
Hardness Duro A, pts.	55	52	60	60	59	50
Specific Gravity	1.063	1.064	1.068	1.071	1.069	1.038
Compression Set, % 22hrs. @ 100°C	68	75	56	53	57	58
Low Temperature Properties						
Low Temperature Impact - Brittleness						
Brittle Point, as molded, all pass, °C	<-75	<-75	-73	-73	<-75	-60
After Air Oven Aging, all pass, °C	<-75	<-75	<-75	<-75	<-75	<-75
Low Temperature Torsion - Gehman						
As molded, Relative Modulus						
T2, °C	-14	-12	-25	-25	-15	-21
T5, °C	-44	-33	-47	-46	-31	-39
T10, °C	-54	-44	-52	-52	-40	-46
T100, °C	-68	-60	-66	-66	-57	-54
Apparent Modulus of Rigidity	160.5	159.8	191.4	204.3	185.4	123.5
Temperature at						
500 psi, °C	-35	-29	-33	-30	-21	-38
5,000 psi, °C	-63	-54	-57	-56	-49	-49
10,000 psi, °C	-66	-58	-60	-59	-52	-53
25,000 psi, °C	-70	-75	-66	-65	-70	-60
50,000 psi, °C	-75	<-75	-75	<-75	<-75	<-75
Aged Vulcanizate Properties						
Air Oven Aging, 70h @ 150°C						
Stress @ 100% Elongation, MPa	9.1	9.6	5.8	5.9	5.7	3.3
, psi	1321	1399	847	860	829	479
Stress Change, %	781	921	192	200	220	123
Tensile Ultimate, MPa	11.1	13.5	10.6	12.4	11.7	9.3
, psi	1612	1957	1532	1795	1699	1356
Tensile Change, %	-1	50	-31	-19	-20	-23
Elongation @ Break, %	125	148	169	194	184	227
Elongation Change, %	-93	-92	-71	-66	-70	-60
Hardness Duro A, pts.	82	83	73	72	71	61
Hardness Change, pts.	27	31	13	12	12	11
Weight Change, %	-11	-11.8	-2.3	-2.3	-2	-1.8

The data of Table III shows results from the evaluation of different dimerate esters in EPDM-Royalene 501. Again, the dimerate esters were evaluated at 30 phr and compared to a conventional paraffinic oil at 60 phr.

5 **Results**

The processing and curing properties show no major differences when compared with paraffinic oils except that since the dimerates are evaluated at lower phr they do produce higher viscosity compounds. The dimerate esters evaluated in Table III are compatible with the elastomers. The dimerate esters also provide higher
10 tensile strength and hardness values than other plasticizers.

Table III shows the low temperature properties for elastomers plasticized with various compounds. The low temperature properties of the compositions plasticized with the dimerate esters are highly significant in comparison to elastomers plasticized with paraffinic oil. Elastomers plasticized with the
15 dimerates possess better lower temperature properties than elastomers plasticized with paraffinic oil, even though the dimerates are at 30 phr and paraffinic oil is at 60 phr. Elastomers plasticized with dimerates exhibit an unexpected combination of high strength and hardness with excellent low temperature properties, and such properties can have importance in applications such as V-belts, radiator hoses, automotive
20 insulation, seals and gaskets.

Additionally, the elastomeric composition of Example 15, which was plasticized with dioctyl sebacate shows roll spew at all temperatures tested, even at room temperature (25°C). Thus, Example 15 indicates that conventional plasticizers, more specifically linear diesters, are not sufficiently compatible with elastomeric
25 compositions so as to provide superior low temperature properties.

The air oven aging results show that the dimerates are essentially equal to the paraffinic oil in weight loss, but the air oven loss for the dimerate esters is significantly less than when conventional plasticizers such as dioctyl sebacate, and tallate compounds are used.

Glass transition data for the EPDM compositions plasticized with dimerate esters RX-13804 and RX-13824 further illustrate the efficacy of the disclosed plasticizers. For example, the disclosed plasticizers provide glass transition temperatures in EPDM which are comparable to those achieved with the conventional plasticizers, dioctyl sebacate and paraffinic oil (even though a significantly lower
5 content of the dimerate plasticizer is used to plasticize the EPDM).

TABLE III

Example	3	13	14	15	16
Royalene 501	100.00				
N-550	60.00				
Kadox 930	5.00				
Stearic Acid	1.00				
RX-13804	30.00	--	--	--	--
RX-13824	---	30.00	---	---	---
RX-13853	---	---	30.00	---	---
Plasthall DOS	---	---	---	30.00	---
Sunpar 2280	---	---	---	---	60.00
Subtotal	196.00	196.00	196.00	196.00	226.00
Mill Addition					
Sulfur	0.80				
Premix MBT	0.94				
Premix TMTD	0.63				
Premix DPTT	0.63				
Premix TDEC	0.63				
Total	199.61	199.61	199.61	199.61	229.61
Major Variable	RX-13804	RX-13824	RX-13853	Plasthall DOS	Sunpar 2280
<u>Processing Properties</u>					
Viscosity and Curing Properties					
Mooney Viscosity at 275°F(135°C)					
Minimum Viscosity	27.2	29	24.5	27.5	15.4
t ₅ , minutes	6.2	6.6	8.2	5.7	9
t ₁₀ , minutes	7.4	7.8	9.3	6.8	10.8
t ₃₅ , minutes	10.1	10.5	17.2	9.1	14.6
Oscillating Disc Rheometer at 320°F(160°C)					
M _L	4.9	6	4.4	5.2	2.5
M _H	32.7	37.1	20.6	42.6	21
t _{c2} , minutes	2.3	2.3	2.7	2.2	3
t' _c (90), minutes	5.2	5.7	7	6.2	7.5
1.25*t' _c (90), minutes	6.5	7.1	8.8	7.7	9.4
Cure Rate Index	35.2	29.9	23.1	25	22.2
<u>Vulcanizate Properties</u>					
<u>Roll Spew</u>					
Temperature @ -40°C					
24 hours	NONE	NONE	NONE	YES	NONE
48 hours	NONE	NONE	NONE	YES	NONE
72 hours	NONE	NONE	NONE	YES	NONE
96 hours	NONE	NONE	NONE	YES	NONE
Temperature @ -3°C					
24 hours	NONE	NONE	NONE	YES	NONE
48 hours	NONE	NONE	NONE	YES	NONE
72 hours	NONE	NONE	NONE	YES	NONE
96 hours	NONE	NONE	NONE	YES	NONE
Temperature @ 25°C					
24 hours	NONE	NONE	NONE	YES	NONE
48 hours	NONE	NONE	NONE	YES	NONE
72 hours	NONE	NONE	NONE	YES	NONE
96 hours	NONE	NONE	NONE	YES	NONE

Example	3	13	14	15	16
<u>Original Physical Properties</u>					
Stress @ 100% Elongation, MPa	1.6	1.7	0.8	2.2	1.2
, psi	225	240	120	315	170
Stress @ 200% Elongation, MPa	2.9	3.1	1.2	4.3	2.2
Stress @ 300% Elongation, MPa	4.2	4.5	1.6	6.2	3.4
Tensile Ultimate, MPa	14.8	14.6	4.2	11.3	13.8
, psi	2150	2120	615	1645	2005
Elongation @ Break, %	825	785	1000	555	815
Hardness Duro A, pts.	57	57	51	59	48
Specific Gravity	1.068	1.068	1.060	1.070	1.038
Compression Set, % 22hrs. @ 100°C	67	64	85	58	70
<u>Low Temperature Properties</u>					
<u>Low Temperature Impact - Brittleness</u>					
Brittle Point, as molded, all pass, °C	>-75	>-75	>-75	>-75	-70
After Air Oven Aging @ 150°C, all pass, °C	>-75	>-75	-70	>-75	-70
After Air Oven Aging @ 169°C, all pass, °C	-60	-65	-70	>-75	-70
<u>Low Temperature Torsion- Gehman</u>					
As molded, Relative Modulus					
T2, °C	-29	-28	-6	-40	-25
T5, °C	-50	-47	-43	-53	-41
T10, °C	-54	-53	-55	-58	-47
T100, °C	-64	-62	-66	-70	-55
Apparent Modulus of Rigidity	142.6	152	86.8	185.9	90.2
Temperature at					
500 psi, °C	-42	-39	-47	-46	-42
5,000 psi, °C	-60	-58	-64	-63	-53
10,000 psi, °C	-64	-61	-67	-66	-55
25,000 psi, °C	-67	-64	-69	-75	-64
50,000 psi, °C	-70	-70	>75	>-75	-70
<u>Aged Vulcanizate Properties</u>					
<u>Air Oven Aging, 70h @ 150°C(302°F)</u>					
Stress @ 100% Elongation, MPa	3.2	3.3	2.7	7.8	2.3
, psi	465	475	390	1135	340
Stress Change, %	107	98	225	260	100
Tensile Ultimate, MPa	11.1	12.5	10.7	14.6	10.7
, psi	1610	1815	1550	2115	1555
Tensile Change, %	-25	-14	152	29	-22
Elongation @ Break, %	310	350	410	185	365
Elongation Change, %	-62	-55	-59	-67	-55
Hardness Duro A, pts.	65	65	64	81	56
Hardness Change, pts.	8	8	13	22	8
Weight Change, %	-1.8	-1.8	-3.5	-15	-1.5

Example	3	13	14	15	16
Air Oven Aging, 70h @ 169°C(336°F)					
Stress @ 100% Elongation, MPa	4.8	5.1	7.2	11.9	2.6
psi	690	735	1040	1720	375
Stress Change, %	207	206	767	446	121
Tensile Ultimate, MPa	6.5	6.9	7.8	12.9	6.0
psi	940	1000	1130	1875	870
Tensile Change, %	-56	-53	84	14	-57
Elongation @ Break, %	130	130	110	110	190
Elongation Change, %	-84	-83	-89	-80	-77
Hardness Duro A, pts.	70	70	75	84	57
Hardness Change, pts.	13	13	24	25	9
Weight Change, %	-3.4	-3.2	-8.3	-15.4	-3.4
Glass Transition, T_g, °C	-55.1	-53.4	--	-61.7	-50.3

Table IV compares the formulation of Example 3 to one containing UBS 020602, which has essentially the same molecular composition as RX-13804 (the ester additive in the formulation of Example 3), but is substantially hydrogenated. The study was done with the same elastomer used in Tables I and III (Royalene 501) and all tests were conducted the same as in Tables I - III. The main differences seen between the two formulations is the UBS 020602 provides moderately better heat aging properties, which could be significant for critical high temperature applications.

TABLE IV

Example	3	17
Royalene 501	100.00	→
N-550	60.00	→
Kadox 930	5.00	→
Stearic Acid	1.00	→
RX-13804	30.00	---
UBS 020602	---	30.00
Subtotal	196.00	196.00
Mill Addition		
Spider Sulfur	0.80	→
Premix MBT	0.94	→
Premix TMTD	0.63	→
Premix DPTT	0.63	→
Premix TDEC	0.63	→
Total	199.61	199.61
Major Variable	RX-13804	UBS 020602
<u>Processing Properties</u>		
<u>Viscosity and Curing Properties</u>		
Mooney Viscosity at 135°C(275°F)		
Minimum Viscosity	30	29.6
t5, minutes	5.8	5.4
t10, minutes	7	6.7
t35, minutes	9.7	9.8
Oscillating Disc Rheometer at 160°C(320°F)		
M _L	5.6	5.9
M _H	34.1	36.9
t ₂ , minutes	2.2	2.2
t' _c (90), minutes	4.8	6.5
1.25*t' _c (90), minutes	6	8.1
Cure Rate Index	37.6	23.1
<u>Vulcanizate Properties</u>		
<u>Roll Spew</u>		
Temperature @ -40°C		
24 hours	NONE	NONE
48 hours	NONE	NONE
72 hours	NONE	NONE
96 hours	NONE	NONE
Temperature @ -3°C		
24 hours	NONE	NONE
48 hours	NONE	NONE
72 hours	NONE	NONE
96 hours	NONE	NONE
Temperature @ 25°C		
24 hours	NONE	NONE
48 hours	NONE	NONE
72 hours	NONE	NONE
96 hours	NONE	NONE

Example	3	17
<u>Original Physical Properties</u>		
Stress @ 100% Elongation, MPa	1.5	2.1
, psi	220	300
Stress @ 200% Elongation, MPa	2.9	4.3
Stress @ 300% Elongation, MPa	4.3	6.1
Tensile Ultimate, MPa	14.3	13.3
, psi	2080	1930
Elongation @ Break, %	805	590
Hardness Duro A, pts.	57	60
Specific Gravity	1.067	1.068
Compression Set, % 22hrs.	71	58
<u>Low Temperature Properties</u>		
Low Temperature Impact - Brittleness		
Brittle Point, as molded, all pass, °C	>-75	>-75
After Air Oven Aging @ 150°C	>-75	>-75
After Air Oven Aging @ 169°C	-70	-70
Low Temperature Torsion- Gehman		
As molded, Relative Modulus		
T2, °C	-34	-38
T5, °C	-49	-51
T10, °C	-55	-55
T100, °C	-65	-65
Apparent Modulus of Rigidity	172	198
Temperature at		
500 psi, °C	-41	-41
5,000 psi, °C	-60	-59
10,000 psi, °C	-63	-62
25,000 psi, °C	-67	-65
50,000 psi, °C	-72	-75
<u>Aged Vulcanizate Properties</u>		
Air Oven Aging, 70h @ 150°C		
Stress @ 100% Elongation, MPa	3.2	4.1
, psi	470	595
Stress Change, %	114	98
Tensile Ultimate, MPa	10.8	11.3
, psi	1570	1640
Tensile Change, %	-25	-15
Elongation @ Break, %	280	220
Elongation Change, %	-65	-63
Hardness Duro A, pts.	67	67
Hardness Change, pts.	10	7
Weight Change, %	-1.9	-1.2

Example	3	17
Air Oven Aging, 70h @ 169°C		
Stress @ 100% Elongation,	4.7	5.2
, psi	680	760
Stress Change, %	209	153
Tensile Ultimate, MPa	6.6	8.4
, psi	955	1215
Tensile Change, %	-54	-37
Elongation @ Break, %	130	145
Elongation Change, %	-84	-75
Hardness Duro A, pts.	71	70
Hardness Change, pts.	14	10
Weight Change, %	-3.0	-1.6

In the following examples provided in Table V, cyclic dimerate esters were applied to Natural Rubber (SMR CV 60). The dimerate esters were evaluated at 15 phr and compared to a conventional napthenic oil at 30 phr (i.e., the conventional rubber plasticizer was added to the elastomer composition at twice the amount of the rubber plasticizers disclosed herein).

Results

The processing and curing properties show no major differences except that since the dimerates are evaluated at lower phr they do produce higher viscosity compounds. Compatibility data (*i.e.*, lack of roll spew) show that the dimerate ester evaluated in Table V is compatible with natural rubber. The dimerate esters provide higher tensile strength and hardness values than other plasticizers.

Table V shows the low temperature properties for elastomers plasticized with various compounds. The low temperature properties of the compositions plasticized with dimerate esters are highly significant in comparison to elastomers plasticized with paraffinic oil. For example, even though the dimerates are at 15 phr and napthenic is at 30 phr, the dimerates provide substantially equal low temperature properties. The combination of high strength and hardness with excellent low temperature properties are important for applications such as hoses, automotive isolators, seals and gaskets.

Additionally, the dimerate esters are significantly lower in volatility when compared to napthenic oil.

TABLE V

Example	18	19	20	21	22
SMR CV 60	100.00				
Kadox 930	5.00				
Stearic Acid	2.00				
N 330	35.00				
Process Oil C-255-E	30.00	---	---	---	---
RX-13804	---	15.00	---	---	---
RX-13824	---	---	15.00	---	---
RX-13805	---	---	---	15.00	---
RX-13896	---	---	---	---	15.00
<u>Mill Addition</u>					
Sulfur	2.25				
Santocure TBBS	0.70				
Total	174.95	159.95	159.95	159.95	159.95

Major Variable	Process Oil C-255-E	RX- 13804	RX- 13824	RX- 13805	RX- 13896
<u>Processing Properties</u>					
<u>Viscosity and Curing Properties</u>					

Mooney Viscosity at 168°C(335°F)

Minimum Viscosity	32.9	34.1	30.9	31.5	28.6
t5, minutes	3.4	1.8	2.4	2.2	2.6
t10, minutes	3.8	2.6	3	2.9	3
t35, minutes	4.3	3.5	3.8	3.6	3.6

Oscillating Disc Rheometer at 168°C(335°F)

M _L	4.3	6.1	5.8	6.7	6.7
M _H	4.5	6.1	5.8	6.7	6.7
t ₂ , minutes	2.5	2	2.3	2.2	2.2
t' _c (90), minutes	3.6	3.1	3.4	3.3	3.4
1.25*t' _c (90), minutes	4.5	3.9	4.3	4.1	4.3
Cure Rate Index	92.6	92.6	91.7	92.6	80

Example	18	19	20	21	22
<u>Original Physical Properties</u>					
Stress @ 100% Elongation, MPa	0.8	1.1	1.2	1.1	1.2
, psi	115	160	170	160	170
Stress @ 200% Elongation, MPa	1.6	2.4	2.6	2.4	2.6
Stress @ 300% Elongation, MPa	3.1	4.7	5	4.7	5
Tensile Ultimate, MPa	16.3	23.6	24.2	23.0	22.5
, psi	2365	3420	3505	3330	3260
Elongation @ Break, %	695	700	705	700	670
Hardness Duro A, pts.	40	46	47	46	47
Specific Gravity	1.049	1.065	1.067	1.068	1.069
<u>Low Temperature Properties</u>					
<u>Low Temperature Impact - Brittleness</u>					
Brittle Point, as molded, all pass, °C	-55	-60	-55	-55	-55
<u>Low Temperature Torsion - Gehman</u>					
As molded, Relative Modulus					
T2, °C	-42	-47	-49	-48	-49
T5, °C	-54	-57	-57	-57	-58
T10, °C	-58	-59	-59	-59	-60
T100, °C	-64	-65	-65	-65	-65
Apparent Modulus of Rigidity	65	103	118	118	102
Temperature at					
500 psi, °C	-57	-56	-56	-56	-57
5,000 psi, °C	-64	-64	-63	-63	-64
10,000 psi, °C	-65	-65	-64	-64	-65
25,000 psi, °C	-67	-68	-65	-65	-68
50,000 psi, °C	-69	-69	-69	-69	-69
<u>Air Oven Aging, 70h @ 100°C</u>					
Stress @ 100% Elongation, MPa	1.1	1.1	1.1	1.1	1.1
, psi	165	160	165	160	160
Stress Change, %	43	0	-2.9	0.0	-5.9
Tensile Ultimate, MPa	4.4	4.3	3.6	3.9	3.1
, psi	635	630	520	570	450
Tensile Change, %	-73	-82	-85	-83	-86
Elongation @ Break, %	290	270	240	260	220
Elongation Change, %	-58	-61	-66	-63	-67
Hardness Duro A, pts	46	40	41	39	39
Hardness Change, pts.	6	-6	-6	-7	-8
Weight Change, %	-13	-0.90	-0.47	-0.48	-0.43

In the following examples provided in Table VI, cyclic dimerate esters were applied to Polychloroprene (Neoprene WRT). Again, the dimerate esters were evaluated at 15 phr and compared to a conventional naphthenic oil at 30 phr (i.e., the conventional rubber plasticizer was added to the elastomer composition at twice the amount of the rubber plasticizers disclosed herein).

Results

The processing and curing properties show no major differences except that since the dimerates are evaluated at lower phr they do produce higher viscosity compounds. Compatibility data show that the dimerate ester evaluated in Table VI is compatible, as indicated by the lack of roll spew and low weight loss in air oven aging. The dimerate ester provides higher tensile strength and hardness values than other plasticizers.

Table VI shows the low temperature properties for elastomers plasticized with various compounds. The low temperature properties of the composition plasticized with the dimerate ester are highly significant in comparison to elastomers plasticized with paraffinic oil. For example, even though the dimerate is at 15 phr and the processing oil at 30 phr, the dimerate provides equal low temperature properties. The combination of high strength and hardness with excellent low temperature can have importance in applications such as V-belts, radiator hoses, automotive insulation, seals and gaskets.

Additionally, the dimerate ester is significantly lower in volatility when compared to the naphthenic oil (air oven aging).

TABLE VI

Example	23	24
Neoprene WRT	100.00	→
Stearic Acid	2.00	→
Octamine	1.00	→
Mag Ox TN16	2.20	→
N 774	70.00	→
Premix TMTD	0.30	→
Process Oil C-255-E	30.00	---
RX-13804	---	15.00
Subtotal	205.50	190.50
<u>Mill Addition</u>		
PB(ETU)75	0.80	→
Kadox 930	5.00	→
Total	211.30	196.30
<u>Processing Properties</u>		
<u>Viscosity and Curing Properties</u>		
Mooney Viscosity at 135°C(275°F)		
Minimum Viscosity	16.6	36.2
t5, minutes	9.5	7.3
t10, minutes	10.8	8.2
t35, minutes	13.8	10.3
Oscillating Disc Rheometer at 160°C(320°F)		
M _L	3.1	8
M _H	19.1	50.7
t _s 2, minutes	3.6	2.5
t'c(90), minutes	14.8	17.3
1.25*t'c(90), minutes	18.5	21.7
Cure Rate Index	8.9	6.7

Example	23	24
<u>Original Physical Properties</u>		
Stress @ 100% Elongation, MPa	2.5	4.8
psi	360	690
Stress @ 200% Elongation, MPa	6.5	13.5
Stress @ 300% Elongation, MPa	12.3	---
Tensile Ultimate, MPa	13.2	15.8
, psi	1920	2295
Elongation @ Break, %	320	225
Hardness Duro A, pts.	56	69
Specific Gravity	1.342	1.394
<u>Low Temperature Properties</u>		
Low Temperature Impact - Brittleness		
Brittle Point, as molded, all pass, °C	-41	-40
Low Temperature Torsion - Gehman		
As molded, Relative Modulus		
T2, °C	-28	-22
T5, °C	-37	-34
T10, °C	-40	-39
T100, °C	-46	-45
Apparent Modulus of Rigidity	144	232
Temperature at		
500 psi, °C	-40	-24
5,000 psi, °C	-44	-41
10,000 psi, °C	-45	-44
25,000 psi, °C	-48	-45
50,000 psi, °C	-50	-49
<u>Air Oven Aging, 70h @ 125°C</u>		
Stress @ 100% Elongation, MPa	9.9	6.7
, psi	1430	970
Stress Change, %	297	41
Tensile Ultimate, MPa	14.9	16.4
psi	2160	2375
Tensile Change, %	13	3
Elongation @ Break, %	165	205
Elongation Change, %	-48	-9
Hardness Duro A, pts	86	75
Hardness Change, pts.	30	6
Weight Change, %	-13	-0.48

TABLE VII

Materials List for Tables I - VI

<u>Material</u>	<u>Chemical Description</u>	<u>Supplier</u>
Royalene 501	Ethylene-propylene ethylidene norbornene rubber 57/43 EP Ratio	Uniroyal
Royalene 502	ENB third monomer 62/38 EP ratio	Uniroyal
N-550	Carbon Black	Engineering Carbon
Kadox 930	Zinc Oxide	The C.P. Hall Company
Stearic Acid	Stearic Acid, Rubber Grade	The C.P. Hall Company
RX-13577	Tridecyl tallate	The C.P. Hall Company
RX-13782	Capryl Tallate	The C.P. Hall Company
RX-13804	Di(2-ethylhexyl) dimerate (Empol 1016)	The C.P. Hall Company
RX-13805	Di(2-ethylhexyl) dimerate (Empol 1018)	The C.P. Hall Company
RX-13806	Didecyl dimerate	The C.P. Hall Company
RX-13824	Di-tridecyl dimerate	The C.P. Hall Company
RX-13853	Di-hexyldecyl tallate	The C.P. Hall Company
RX-13896	Di(2-ethylhexyl) dimerate (Unidyme 22)	The C.P. Hall Company
SMR CV 60	Natural Rubber	The C.P. Hall Company
N-330	Carbon Black	Degussa
Process Oil C-255-E	Parrafinic Oil	The C.P. Hall Company
Sulfur	Sulfur	The C.P. Hall Company
Santocure TBBS	N-t-butyl-2-benzothiazolesulfenamide	Harwick Standard
UBS 020602	Di (2-ethylhexyl) dimerate (Pripol 1006)	The C.P. Hall Company
Plasthall DOS	Diocetyl Sebacate	The C.P. Hall Company
Sunpar 2280	Parrafinic Oil	Sun Refining
Spider Sulfur	Elemental Sulfur	The C.P. Hall Company
Premix MBT	2-mercaptobenzothiazole	The C.P. Hall Company
Premix TMTD	Tetramethyl thiuram disulfide	The C.P. Hall Company
Premix DPTT	Dipentamethylene thiuram (tetra) sulfide	The C.P. Hall Company
Premix TDEC	Tellurium diethyldithiocarbamate	The C.P. Hall Company
Neoprene WRT	Polychloroprene	R.T. Vanderbilt
Octamine	Octylated diphenylamine	Uniroyal
Mag Oxide TN16	Magnesium Oxide	The C.P. Hall Company
N-774	Carbon Black	Degussa
PB(ETU)75	Ethylene Thiourea 75%	Rhein Chemie